CORRELATION BETWEEN VEGETATION AND SOIL ACIDITY IN SOUTHERN NEW JERSEY.

BY EDGAR T. WHERRY

By southern New Jersey is meant that portion of the state lying south of the Fall-line, which extends from the Atlantic coast near Perth Amboy, southwestward to the Delaware river at Trenton. The geology of this region has been described in many reports issued by the State Geological Survey, and in U. S. Geological Survey folios. The soils have been discussed from an agricultural standpoint in a recent publication of the U. S. Bureau of Soils.[1] Several botanists have studied the vegetation in detail, but have reached widely different conclusions as to its proper geographical classification. The various divisions which have been recognized by these workers, together with data on the geological and chemical relationships, are contrasted in table 1. These divisions have been termed zones, regions, strips, etc., but it seems desirable to have a single term to apply uniformly, and *area* most accurately expresses the desired conception. Six vegetation-areas appear to be sufficiently distinct to justify separate treatment, although there are admittedly in most places no sharp boundaries between them. In the course of vacation outings during the past several years the writer has visited typical localities in all of these areas, and has obtained data as to the relations between the vegetation and a factor not specially considered by previous workers, namely the soil acidity. This has been determined in the field by the indicator method.[2] The results obtained in the Coastal area have already been described,[3] and in the present paper observations on the other areas are recorded.

---

[1]Bonsteel, J. A. Soils of southern New Jersey and their uses. *U. S. Dept. Agr. Bull.* 677, (1918).
[2]*Journ. Wash. Acad. Sci.* **10**: 217–223. 1920.
[3]*Ecology*, **1**: 1920.

TABLE I. VEGETATION—AREAS OF SOUTHERN NEW JERSEY.

References[4]	Northwest	Southwest	South	Central	East	Sea-shore
Hollick, 1899, 3.	Tension zone	Coniferous zone				
Stone, 1907, 453–454	Delaware Valley—West Jersey region		Southern portion of the Cape May peninsula	Pine-barrens	Atlantic Coast strip	Maritime meadows and sea beach
Stone, 1911, 57.	Middle District		Cape May District	Pine-barrens	Coastal strip	Maritime District
Harshberger, 1911, 409, 423.	Transition area		Coniferous area			Salt strand, beach and dune
Harshberger, 1916, 16.	Middle District		Farms reverting to forest	Pine-barrens	Farms reverting to forest	Maritime District
Taylor, 1912, 229; 1915, 9.	(Not pine-barrens)			Pine-barrens	(Not pine-barrens)	
Harper, 1918, 117–124.	Greensand marl or clay belt	Cohansey region	Mainland of the Cape May peninsula	Pine-barrens	Coast strip	Beaches, moving dunes, lagoons and marshes
This paper	Marl area	Cohansey area	Cape May area	Pine-barren area	Coastal area	Maritime area
Dominant geological formations	Cretaceous Pensauken Cape May	Cape May Pensauken Miocene	Cape May	Miocene	Cape May Recent	Cape May Recent
Salts of calcium, etc.	High	Medium	Medium	Low	High	Extreme
Dominant soil reaction	Circumneutral	Subacid	Subacid	Mediacid	Mediacid	Subalkaline

ACIDITIES OF THE SOILS OF THE DIFFERENT GEOLOGICAL FORMATIONS.

For the purposes of the present study the geological formations may be grouped into: Cretaceous, Miocene, Pensauken, Cape May, and Recent. The Cretaceous strata, which outcrop toward the western side of the region, are made up of sand, clay, marl, glauconite, and fossil shells. Salts of calcium, potassium, etc., are relatively large in amount in the water extracts of the soils; and there is enough calcium carbonate present in most of the beds to neutralize any acids which develop in the soils, so that circumneutral reaction is the rule.

The Miocene consists of gravel and sand beds, which were raised above sea level soon after their deposition, and have remained so practically ever since. As a result of long-continued weathering most of the calcium and potassium salts, as well as any calcium carbonate the beds may originally have contained, have been leached out. Acids arising from the decomposition of humus or from any other source remain un-neutralized, and mediacid reaction is present nearly throughout the areas underlain by Miocene formations. In the deeper parts of the soil, however, the acidity diminishes, being as low as minimacid at depths of a few decimeters; and the banks of streams, road cuts, etc., occasionally expose low acid material.

The sand and gravel classed as the Pensauken formation, with which the Bridgeton is here included, is believed to have been derived by erosion of the Miocene, and the soils of the two are practically identical in the respects under consideration.

The Cape May formation consists of sand and clay of late Quaternary age, deposited by streams swollen by water from the great ice sheet, which reached nearly to the northern edge of the present

[4]Hollick, Arthur. The relation between forestry and geology in New Jersey. *Am. Nat.*, **33**, 1–14. 1899. Also in *Ann. Rept. State Geologist of New Jersey for 1899:* 177–201. 1900.

Stone, Witmer. The life areas of southern New Jersey. *Proc. Acad. Nat. Sci. Phila., 1907:* 452–459.

——— The plants of southern New Jersey, with especial reference to the flora of the pine barrens and the geographic distribution of the species. *Ann. Rept. N. J. State Mus. for 1910:* 21-828. 1911.

Harshberger, John W. Phytogeographic survey of North America, 790 pp. Leipzig, 1911.

——— The vegetation of the New Jersey pine-barrens. An ecologic investigation. 329 pp. Philadelphia, 1916.

Taylor, Norman. On the origin and present distribution of the pine-barrens of New Jersey. *Torreya*, **12**: 229–242. 1912.

——— Flora of the vicinity of New York. A contribution to plant geography. *Mem. N. Y. Bot. Garden*, **5**: 1–683. 1915.

Harper, Roland M. A sketch of the forest geography of New Jersey. *Bull. Geogr. Soc. Phila.*, **16**: 107–125, 1918.

region. Because of containing considerable rock-flour, and of not having been long (geologically speaking) subjected to weathering, this formation yields soils relatively high in calcium and potassium salts. The content of calcium carbonate is less, however, than in the Cretaceous, so that acids are not as completely neutralized, and subacid reactions are most characteristic of the areas underlain by the Cape May.

The soil acidities of the several vegetation-areas are determined by the distribution of these different geological formations in them. In the Marl area— named after the most characteristic material represented—the salt content averages high and acidity low because the Cretaceous strata outcrop in many places. More or less isolated patches of Cape May and of Pensauken deposits occur in the area, and show locally lower salt content and greater acidity. In the Cohansey area Cape May deposits are most widespread, so that the average acidity is moderate; but again isolated patches occur, in this case occupied by Miocene and Pensauken deposits, in which the acidity is high. The Cape May and Pine-barren areas are occupied essentially by single geological formations, and show the acidities characteristic of these in each case. The peculiar features of the Coastal and Maritime areas have been discussed in the paper above referred to.

Relation of Soil Acidity to Plant Distribution.

Tests have been made of the soils surrounding the roots of a number of plants in each of these areas, and as the results obtained have furnished evidence in support of the view that plant distribution is intimately connected with soil acidity, a few typical instances may well be described here.

The rattlesnake fern, *Botrychium virginianum*, which in other regions is most frequently found in circumneutral soils, is common in southern New Jersey in the Marl area, and occasional in the Cohansey and Cape May areas; it appears to be quite absent, however, from the Pine-barren and Coastal areas. As there is no physical barrier to its spreading into the latter areas, the inference seems justified that when its spores reach these areas their germination is prevented by the high degree of acidity present. By way of contrast, the curly-grass fern, *Schizaea pusilla*, is limited to the Pine-barren and Coastal areas, and actual tests of its soils have shown mediacid reaction. Here there seems to exist an inability of the plant to become established except where the acidity is high.

The ebony spleenwort, *Asplenium platyneuron*, which is usually found in soils of but moderate acidity, grows in all the vegetation areas of southern New Jersey. In the Pine-barren and Coastal ones, however, it is found only on steep banks, where the acidity may be rather lower than in level places. The oak fern, *Phegopteris* (*Dryopteris*) *dryopteris*, a plant characteristic of cool shaded places where the soils are circumneutral, would hardly be expected to become established in the warm climate of southern New Jersey. But that its spores actually reach this region is shown by the occurrence of a colony in an old well in the Pine-barren area, where the combination of low acidity and cool atmosphere is of course attained.

In the paper above cited, as well as in studies in other regions, Dr. R. M. Harper has used the percentage of evergreen—chiefly coniferous—trees as an index of the relative poorness in salts of the soils of individual vegetation-areas. While a relation of this sort undoubtedly exists, it would be a mistake to infer from it that all conifers are alike in their soil requirements. The pitch pine, *Pinus rigida*, thrives in the salt-poor mediacid soils of the Pine-barren area; but the scrub pine, *P. virginiana*, is very rare in that area, apparently requiring subacid soil reaction and moderate salt content such as are present in the Marl area. The yellow pine, *P. echinata*, which is intermediate in its characters between the two others, appears to be relatively indifferent as to soil conditions, and grows about equally well in the Pine-barrens and the Marl area.

The Canada lily, *Lilium canadense*, elsewhere a circumneutral soil species, grows in southern New Jersey, as would be expected, only in the Marl area. The related turk's-cap lily, *L. superbum*, which seems to be partial to highly acid soils, is on the other hand widespread in southern New Jersey, and most abundant in the Pine-barren area. In the bog near Lindenwold, famous for its remarkable flora, both of these lilies grow, which might be taken as evidence that they are not particularly different in their soil acidity requirements after all. But actual observation shows that the first species grows chiefly at the lower levels in the bog, where Cretaceous strata outcrop and the soils are circumneutral, while the second occurs higher, in the highly acid soils derived from the Pensauken sand.

Among orchids many species are partial to highly acid soils, and are in southern New Jersey most abundant in the Pine-barren area. In the genus *Habenaria*, subgenus *Blephariglottis*, the three species

with fringed but simple lips, namely the white, large yellow, and small yellow fringed orchids, *H. blephariglottis*, *H. ciliaris*, and *H. cristata*, respectively, are extremely abundant in the bogs of that area. On the other hand the species with three-parted lips, the green, large purple, small purple, and short-fringed purple fringed orchids, *H. lacera*, *H. grandiflora*, *H. psycodes*, and *H. peramoena*, are limited to the areas surrounding the Pine-barrens, where they find soils of lower acidity.

The majority of the buttercup family, *Ranunculaceae*, appear in other regions to be partial to circumneutral soils, and it is a striking fact that members of this family are almost unknown in the Pine-barren area. The marsh marigold, *Caltha palustris*, has been observed in the Lindenwold bog, but it grows only at the lower levels, where the soil is circumneutral. The columbine, *Aquilegia canadensis*, can withstand a mediacid reaction if the salt content of the soils is high enough, as in the Coastal area.

The Heath family, Ericaceae, together with certain closely related ones, are treated in detail elsewhere; but it may be noted here how strikingly their distribution is controlled by the soil acidity. The *Pyrolas* favor subacid soils, and are very rare in the Pine-barrens though common in the Marl area. The same is true of the pink azalea, *Azalea nudiflora*, the deerberry, *Polycodium stamineum*, and the narrow-leaved low-bush blueberry, *Vaccinium pennsylvanicum* (*angustifolium*). Numerous other members of the family are, however, more abundant in the Pine-barrens than in any other area, evidently because of their preference for soils low in salts and high in acidity. When these ericaceous species grow in the Marl area, they avoid the places where calcareous marly strata actually outcrop, and grow instead upon patches of acid Pensauken sand.

Bearing of Soil Reaction on the Origin of the Pine Barren Flora

In papers cited in connection with table 1, Harshberger and Taylor have independently elaborated a theory of origin of the flora of the New Jersey Pine-barrens, based on the alleged remaining above sea-level of the Miocene strata ever since their first emergence at the close of the Miocene period. According to this theory, the area occupied by these strata has been an island up to comparatively recent geological time, and the plants now growing there represent direct descendants of those of the Miocene period. This theory has been criticized from the botanical standpoint by Fernald, Harper, and others, and recent advances in geological knowledge are

decidedly unfavorable to it. Barrell[1] has pointed out that certain peneplains of the eastern United States of Pliocene and Pleistocene age have resulted from marine transgression, and it seems extremely improbable that any part of southern New Jersey could have escaped submergence during these epochs.

A consideration of the soil acidity relations indicates, however, that there is an adequate explanation of the presence of this flora, entirely aside from the geological history of the New Jersey Pine-barren area. The peculiar and isolated character of the flora of this area has been greatly overestimated, because of incomplete knowledge of the floras of surrounding regions. McAtee[2] has recently shown that over 70 per cent of the most typical plants of the New Jersey Pine-barrens grow in favorable places ineastern Maryland; and Harper[3] has noted the presence of pine-barren plants in a strip of land crossing the Delaware peninsula. Not more than five or six of the members of the Pine-barren flora are actually endemic, the great majority of them ranging, as shown by Stone, for considerable distances northward or southward (or in both directions) from New Jersey. Nevertheless the plant association of the Pine-barren area is sufficiently striking to warrant a discussion of its origin.

The flora of the New Jersey Pine-barrens includes many plants which have migrated northward from the Coastal Plain of the southern states, such as the grass-pink orchid, *Limodorum tuberosum;* others from the southern Appalachian mountains, such as the rhododendron, *Rhododendron maximum;* and still others from arctic bogs, such as the buckbean, *Menyanthes trifoliata.* The one thing which all of these plants have in common is their adaptation to growth in soils of low salt content (as pointed out by Harper, *loc. cit.*) and *high acidity.* In the opinion of the present writer, an adequate explanation of their association to make up the flora of the New Jersey Pine-barrens is the fact that this area possesses these two characteristics to such a marked degree.

---

[1]Post Jurassic history, etc. (Abstract). *Bull. Geol. Soc. Am.*, **24**: 691. 1913. The Piedmont terraces of the northern Appalachians. *Amer. Journ. Sci.*, **49**: 227–258, 327–362, 407–428, (1920).

[2]A sketch of the natural history of the District of Columbia. *Bull. Biol. Soc. Wash.*, **1**: 86. 1918.

[3]A forest reconnaisance of the Delaware peninsula. *Journ. Forestry*, **17**: 551. 1919.